RESEARCH DEPARTMENT

A TELEVISION CHECK RECEIVER FOR BAND I, CHANNEL I

Report No. G-064

(1955/35)

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

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R.E. Jones
C.G. Mayo, M.A., B.Sc., M.I.E.E.

W Proctor Wilson

(W. Proctor Wilson)

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SUMMARY

A television receiver suitable for picture-quality checking is described; it is designed for the reception of double-sideband signals on Channel 1, vision carrier 45 Mc/s. The receiver gives negligible phase and amplitude distortion of modulation frequencies up to 3 Mc/s, and provides 35 dB suppression of the sound carrier on 41·5 Mc/s. The output contains full synchronising pulses and the d.c. component; the peak-white signal level across an external load of 75 ohms is 1 volt.

1. INTRODUCTION

The receiver to be described was designed for checking the quality of television pictures at Kingswood Warren from the Alexandra Palace transmitter; the path length is approximately 21 miles (34 km). Alexandra Palace radiates double-sideband transmissions, and the field strength at 30 ft (9.1 m) above ground level is approximately 4 mV/m. The field strength of stations operating in adjacent channels is low, so that the selectivity of the receiver is not very important. There is, however, the possibility of interference due to locally generated noise. Since the equipment may be used for observing the effect of noise on television pictures it was desirable to minimise the pick-up of local interference.

An inverted-V receiving aerial[1], located in the grounds at Kingswood Warren, is used; it is approximately 300 yards (270 m) from the television laboratories. The aerial is connected to an amplifier and thence by a balanced line to the main receiver in the television laboratories. After passing through an attenuator and amplifier, the signal passes through the sound-carrier filter and thence through another amplifier to the demodulator. The output of the demodulator is intended to be fed to a high-quality commercial monitor. Fig. 1 shows a block schematic of the complete system, together with the approximate operating levels.

2. DESCRIPTION OF RECEIVER.

2.1. General.

The basic design of the amplifiers is simple and conservative. As suppression of interfering signals in adjacent channels is not important*, no attempt was made to use the valve and incidental stray capacities as elements in stop filters. It was considered that, in the unlikely event of interference from other stations,

* in view of the purpose for which the receiver was designed.

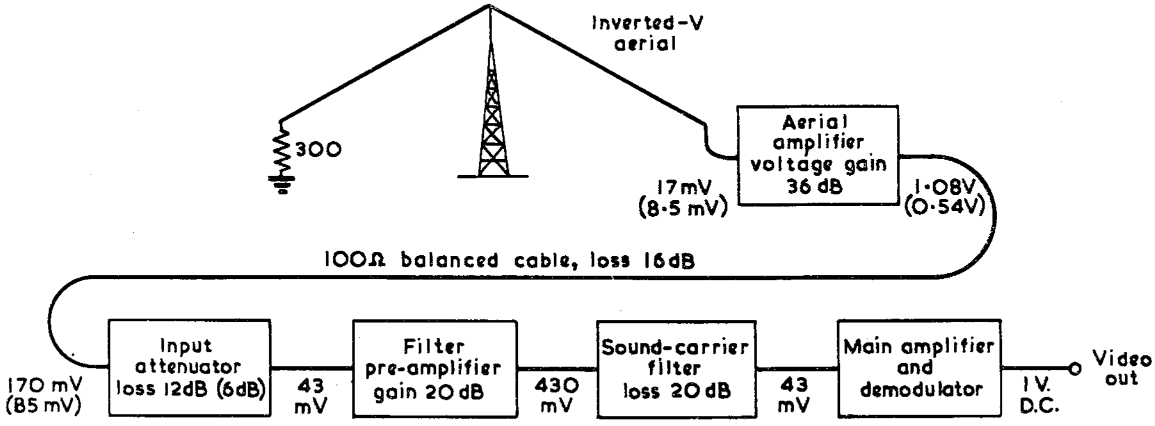


Fig. 1 - Block schematic of complete system

The levels given are the peak white, r.m.s. values of the Alexandra Palace vision carrier. The levels in brackets apply when the reserve transmitter is in use.

this could be dealt with by additional stop filters. The general principle adopted, therefore, is to use amplifying stages in which the stray capacitances are tuned with parallel inductances, each circuit being loaded with a suitable parallel resistance.

For one such circuit the variation of the stage gain with frequency may be written:

$$\frac{V_{r+1}}{V_r} = \frac{\mu_0}{(1+\lambda p)} \tag{1}$$

where V_r and V_{r+1} are the voltages across the anode circuits in the rth and $(r+1)$th stages respectively

μ_0 is a constant

p = ix where x is the frequency deviation from the carrier, normalised such that x = ±1 at a deviation of ±3Mc/s

λ is a factor proportional to the loading resistance (λ is assumed to be $\ll 1$).

The modulus of expression (1) may be written

$$\left|\frac{V_{r+1}}{V_r}\right| = \frac{\mu_0}{\sqrt{1+\lambda^2 x^2}} \approx \mu_0\left(1-\frac{\lambda^2 x^2}{2}\right) \tag{2}$$

If ϕ is the phase difference between V_r and V_{r+1}, the normalised group delay,

with $\lambda x \ll 1$

$$\frac{d\phi}{dx} = -\frac{\lambda}{(1+\lambda^2 x^2)} \approx -\lambda\,(1-\lambda^2 x^2) \tag{3}$$

and the time delay is $\frac{\lambda}{6\pi}(1-\lambda^2 x^2)\,\mu$s. The first term is the group delay, and the second term is the group-delay distortion.

The loading resistance was chosen to make λ about 0·25. At the edge of the band, therefore, the amplitude response falls by 0·25 dB, and the deviation of the group delay from the mid-band value is 0·000 85 μs.

As all circuits of the type described are separated by valves, the overall characteristic is given by summing the attenuation in decibels and the group-delay distortion for each stage. The performance thus obtained can be improved in several ways; in essence these amount to reducing the damping factor in the quadratic expression given by two such simple circuits in cascade. One method involves the addition of tuned series elements, which are equivalent to the "peaking" inductances used in video circuits; another method involves staggered tuning. The method used in this receiver is by resistive feedback between consecutive anodes. This is a simple and flexible method which in this instance enables the total phase distortion to be made negligible (by making the phase distortion of the feedback pairs opposite in sign to that of the other stages); at the same time the variation of amplitude response over the band is greatly reduced. A T network is used in the feedback circuit in order to avoid the inconvenient values required for the π section.

2.2. Aerial Amplifier.

The aerial amplifier incorporates four valve stages. The circuit diagram is shown in Fig. 2 and the frequency characteristic in Fig. 3; the voltage gain at the mid-band frequency is 36 dB. The first two stages are coupled by resistance-loaded tuned circuits with feedback from the anode of V2 to the anode of V1. There is no feedback over the last two stages as a π rather than a T network would be required and the component values are not practicable. The output circuit incorporates a step-down transformer for matching to the balanced transmission line. An "undecoupled" bias resistor is used in this stage to improve the linearity, in order to reduce intermodulation between the sound and vision signals.

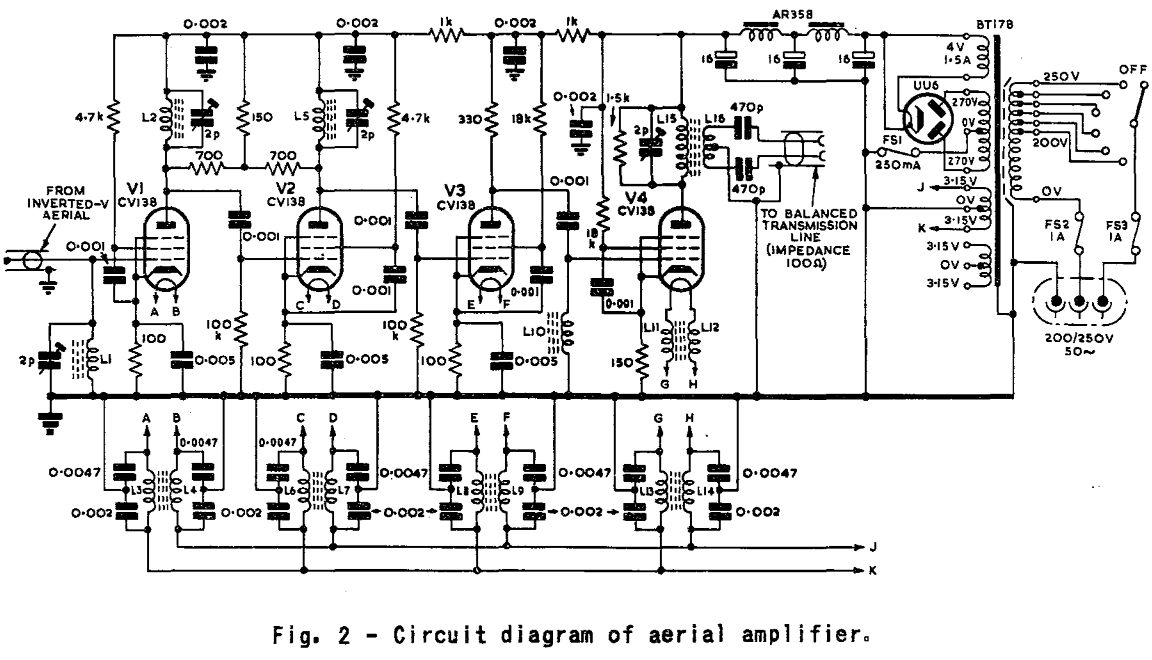


Fig. 2 - Circuit diagram of aerial amplifier.

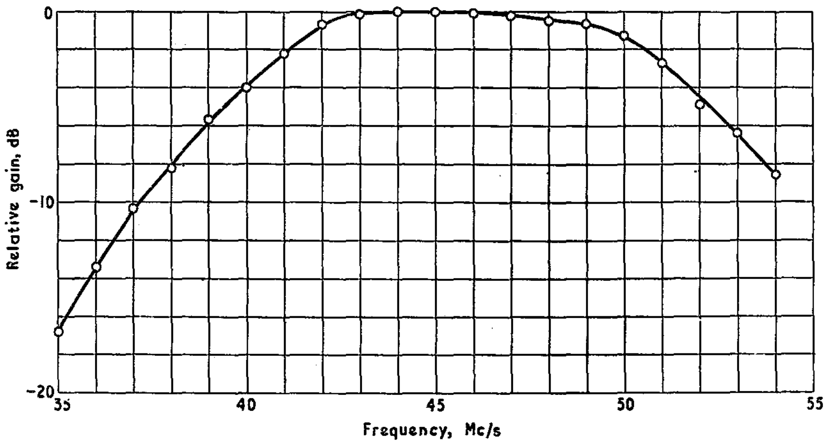


Fig. 3 - Frequency response of aerial amplifier

2.3. Transmission Line.

The transmission line used for coupling the aerial amplifier to the main amplifier in the television laboratories is balanced, and has a solid polythene dielectric. The characteristic impedance is 100 ohms; the attenuation is approximately 16 dB.

2.4. Input Attenuator.

The transmission line is terminated in a 100-ohm balanced to 100-ohm unbalanced transformer, which feeds a 6-step attenuator, each step being 3 dB. This enables the output voltage of the receiver to be adjusted to the correct value, i.e. to give the required video output of approximately 1 volt peak white.

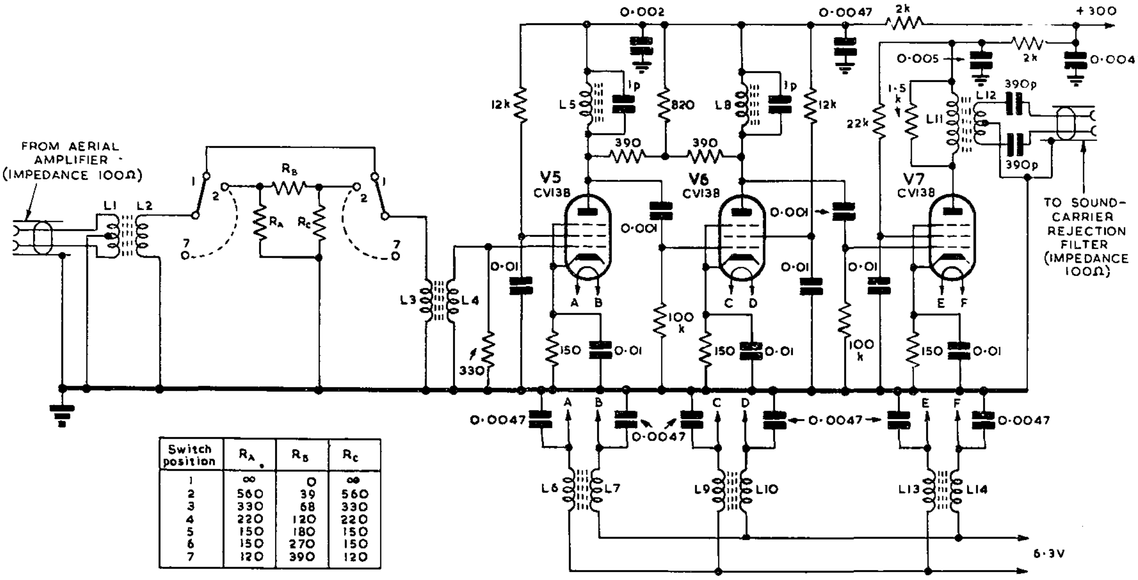
2.5. Filter Pre-amplifier.

This is similar in design to the aerial amplifier. The circuit diagram is shown in Fig. 4; the gain at the mid-band frequency is 20 dB, and the output is a balanced circuit of 100 ohms impedance.

2.6. Sound-carrier Rejection Filter.

The filter was required to provide adequate suppression at 41·5 Mc/s and to pass frequencies exceeding 42 Mc/s with minimum phase distortion. To secure the high discrimination required, two alternative methods presented themselves. One was by means of subtractive methods such as bridges balanced at the frequency to be rejected, of which the bridged-T circuit is an example. It is difficult, using this method, to secure adequate rejection bandwidth without incurring serious phase distortion elsewhere in the band, unless high Q coils are used. On the other hand, if high Q coils are available, subtractive methods are unnecessary; a conventional confluent band-stop filter becomes the more practical proposition.

It was found that Q's of the order of 600 could be obtained with coils of about 12 turns of 0·08 in. (2 mms) diameter tinned copper wire on 1·12 in. (2·8 cm) diameter porcelain formers with air-spaced trimming condensers. Larger inductances



Switch position	R_A	R_B	R_C
1	∞	0	∞
2	560	39	560
3	330	68	330
4	220	120	220
5	150	180	150
6	150	270	150
7	120	390	120

Fig. 4 - Circuit diagram of input attenuator and filter pre-amplifier

were unusable owing to the effect of stray capacitances, while smaller inductances necessitated larger capacitances which in practice have greater losses. There is therefore an optimum working impedance for the actual tuned circuits, and the filter was designed to use such coils, other artifices being used to "fit" the tuned circuits into the filter structure.

The relatively small spacing between the stop and pass frequencies necessitates a high impedance ratio between the series and shunt elements of the confluent band-stop filter. The low impedance series element was therefore made a single turn loop of 0·064 in. (1·6 mm) diameter copper wire, 0·38 in. (0·95 cm) diameter, coupled to a parallel tuned circuit of the type described above. The coupling was made variable in order to adjust the ratio of the transformer thus formed, the setting being a compromise to give the greatest rejection at 41·5 Mc/s with tolerable amplitude distortion at 42 Mc/s. The inductance of the single turn, 0·03 μH, is virtually the series leakage inductance of this otherwise ideal transformer. At frequencies other than the stop frequency, the series reactance will be approximately j8 ohms compared with the characteristic impedance of the filter which is 4 ohms. It is therefore necessary to tune out the reactance of this coil by means of a series condenser which gives a final series impedance over the band of about 1 ohm. This can be neglected relative to the shunt admittance present at the pass frequencies.

The shunt element consists of a series-tuned coil similar to the series coil but connected without impedance transformation. At 41·5 Mc/s both the series and the shunt elements are resonant, the series circuit to maximum impedance and the shunt circuit to minimum impedance, thus giving an attenuation nearly equal to the ratio of their impedances. At higher frequencies the series element looks like a capacitance whereas the shunt element looks like an inductance. This gives a peak in the response curve at 41·7 Mc/s which, with a normally loaded filter, would be almost exactly smoothed out, but at the expense of phase distortion. By increasing the coupling of the series element, the attenuation at 41·5 Mc/s can be increased, at the

same time increasing the magnitude of the peak at 41·7 Mc/s. A compromise was made which gave an attenuation of 34 dB at 41·5 Mc/s and a peak of +4 dB at 41·7 Mc/s. There is a rise of about 1 dB at 42 Mc/s which is compensated by the overall selectivity of the receiver.

As the Q of the filter is high, it is necessary to use capacitative potential dividers to provide a sufficiently smooth adjustment of the resonant frequency of the tuned circuits. This is provided by a miniature pre-set condenser employing P.T.F.E. insulation with a 22 pF silvered mica condenser. While mica insulation has too great a loss to be used in the main tuning condenser, it is quite satisfactory for use in a potential divider with a step down of approximately 10:1. The final trimmer is a 2-8 pF concentric type which is accessible through a hole in the coil screen.

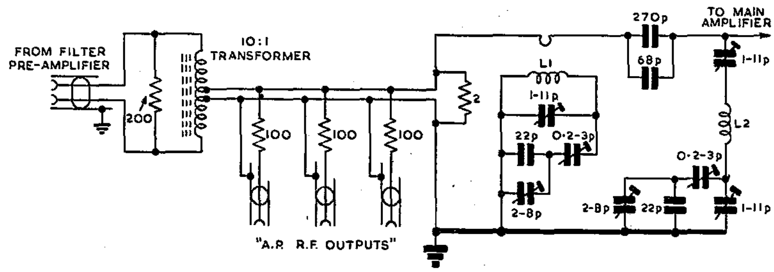


Fig. 5 - Circuit diagram of sound-carrier rejection filter

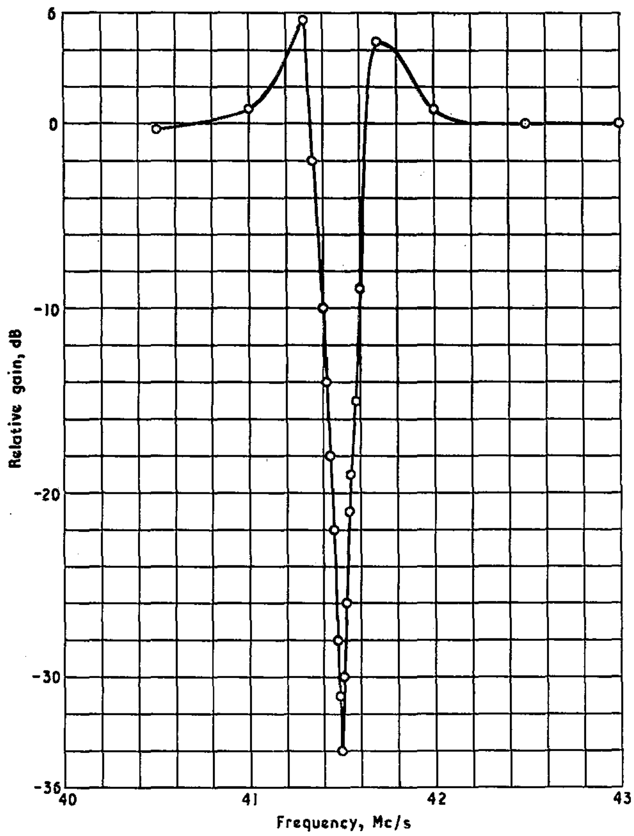


Fig. 6 - Sound carrier rejection filter response

The circuit diagram of the filter is shown in Fig. 5, and the frequency characteristic in Fig. 6. The low impedance of the filter and the requirement of heavy under-damping of the series circuit make it necessary to supply the filter from a 1-ohm source impedance. This is provided by a wideband transformer stepping down from the 100-ohm balanced input to 1 ohm. This 1-ohm circuit is a convenient one from which to take off a complete r.f. television signal for other users. Three output sockets are provided which are connected through 100-ohm resistances to the 1-ohm side of the transformer. This signal includes the sound carrier and has a peak-white vision carrier amplitude of about 40 mV on open circuit with a source impedance of 100 ohms.

2.7. Main Amplifier and Demodulator.

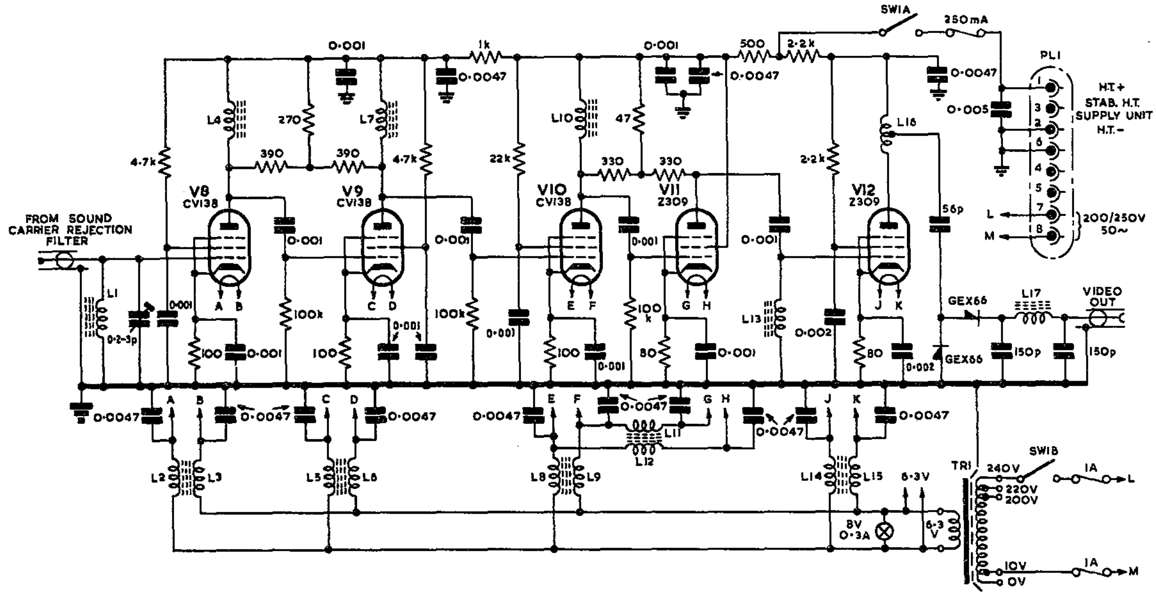


Fig. 7 - Circuit diagram of main amplifier and demodulator

The main amplifier incorporates five amplifying stages and a demodulator; the circuit diagram is shown in Fig. 7. The first four valves are arranged in pairs, with feedback from the anode of one valve to the anode of the previous valve. The demodulator is a conventional voltage doubler which is fed from a step-down transformer. By this means it is possible to provide a complete television waveform, including the d.c. component, with a peak white amplitude of 1 volt across a 75-ohm load; the input-output characteristic is shown in Fig. 8.

3. PERFORMANCE.

Fig. 9 shows the overall frequency response of the equipment, omitting the transmission line between the aerial amplifier and the input attenuator. Fig. 10 shows the modulation-frequency response, and Fig. 11 the overall group-delay response,

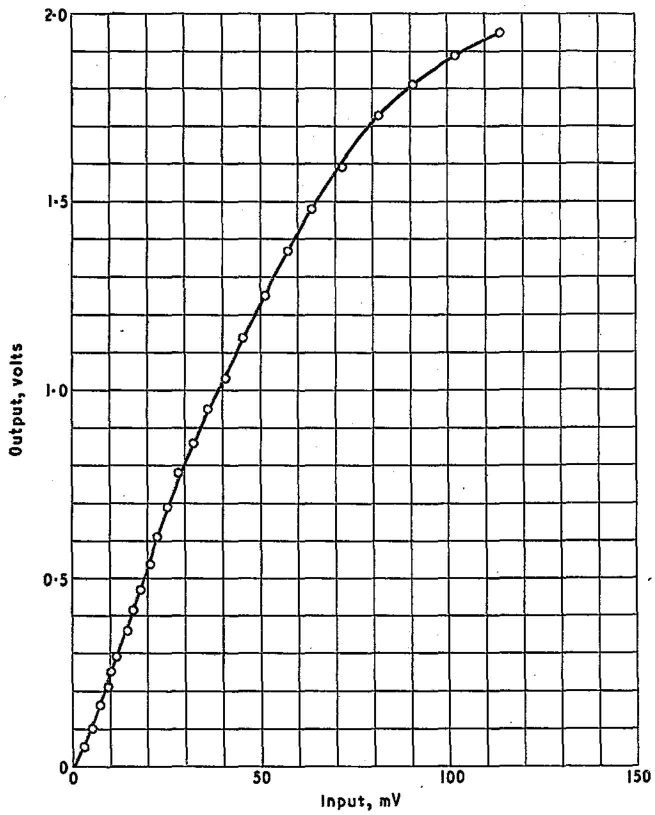


Fig. 8 - Input-output characteristic of main receiver (measured at 45 Mc/s, input attenuator 0 dB)

measured under the same conditions. Summarising these results, the overall frequency response is within ± ½ dB over the vision passband of 45 ± 3 Mc/s. The sound-carrier is suppressed 35 dB relative to the vision carrier, and this amount of rejection has proved satisfactory in practice. The modulation frequency response is flat to within ± ½ dB for all frequencies up to 3·2 Mc/s; the group delay is constant at 0·22 μs for frequencies up to 2·7 Mc/s and rises by 0·06 μs at 3 Mc/s.

The effect of temperature on the sound carrier rejection filter has been measured; the frequency of maximum rejection decreases with an increase in temperature by approximately 1 kc/s per degree centigrade, while the amount of attenuation remains constant. Thus a rise of temperature of 10°C will reduce the attenuation at 41·5 Mc/s by 4 dB if the filter is not retrimmed.

The aerial amplifier has a linear input-output characteristic for inputs up to 27 mV r.m.s.; the corresponding output level is 1·7 V r.m.s. If the input rises above the former value an attenuator having an impedance of 300 ohms should precede the aerial amplifier, otherwise there may be intermodulation between the sound and vision carriers.

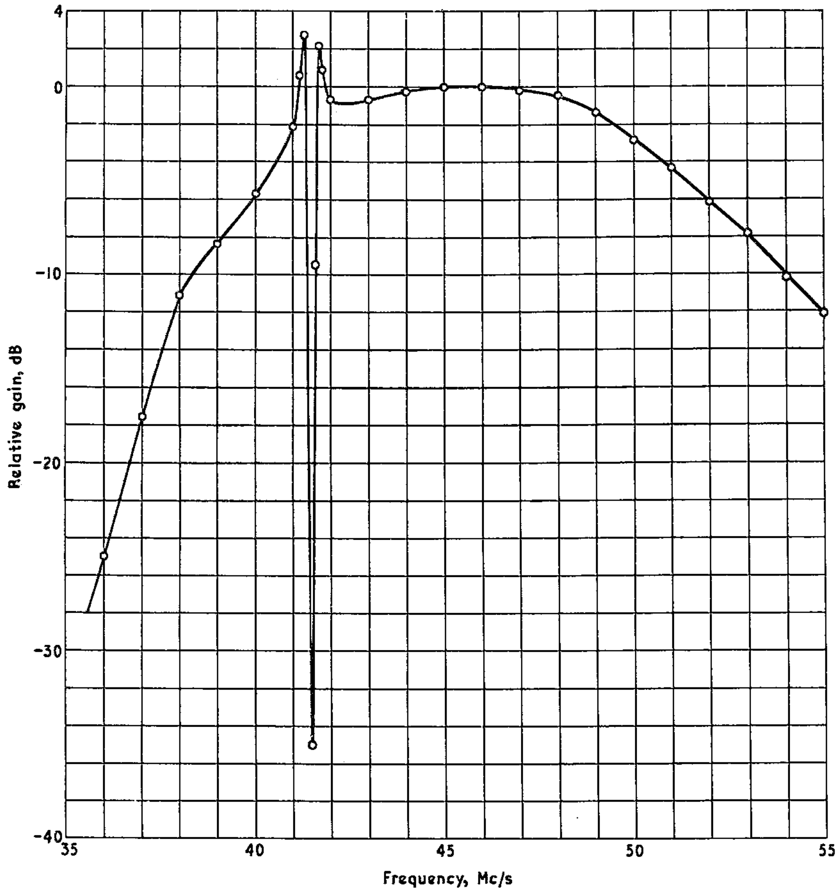


Fig. 9 - Overall frequency response (omitting transmission line)

4. OPERATING INSTRUCTIONS.

The input attenuator should be set to give a peak output of 1 volt across 75 ohms. This can be achieved with a range of signal levels of 40–320 mV at the input of the main receiver. In addition to the demodulated output a double-sideband television signal with sound carrier is available at the sockets marked A.P.R.F. outputs; the open-circuit voltage at these points is approximately 40 mV. The outputs may be loaded or even short-circuited without affecting the performance of the receiver.

The operating anode current of each CV138 valve in the receiver is nominally 10 mA with a screen current of approximately 2·5 mA. The two Z309 valves used should each take an anode current of 20 mA and a screen current of approximately 5·3 mA. The total H.T. current of the aerial amplifier is therefore 50 mA. The main receiver takes 126 mA, of which 38 mA is taken by the filter pre-amplifier and 88 mA by the main amplifier.

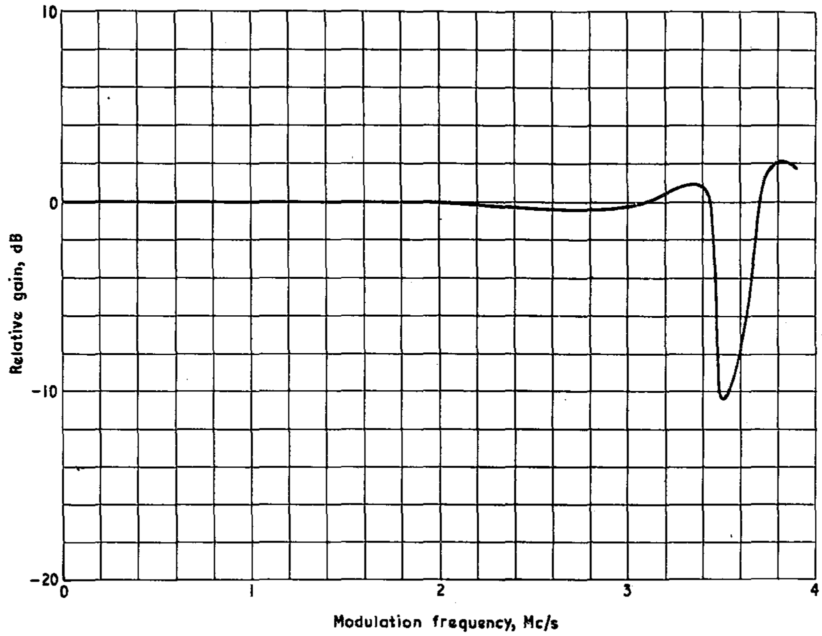


Fig. 10 - Modulation-frequency response

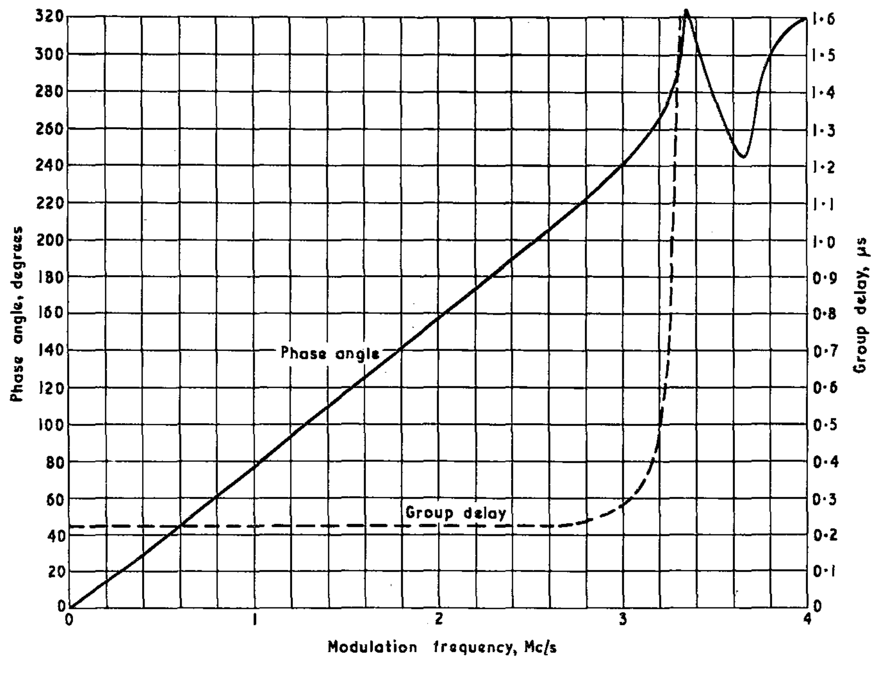


Fig. 11 - Overall phase response and group delay

5. CONCLUSIONS.

A television receiver has been produced which is capable of providing a television waveform virtually free from amplitude and phase distortion, with adequate rejection of the associated sound channel.

6. REFERENCES.

1. "Vertical Half-Rhombic Aerial for Television on 45 Mc/s", Research Department Technical Memorandum No.G1005, April, 1950.